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ABSTRACT: Trade credit limits trigger action in the management of accounts receivable. In practice, these limits are usually set by unaided managerial judgment. Two methodologies are developed based on wealth maximization: information credit limits and risk credit limits. Information limits signal the need for additional credit investigation. Risk credit limits are maximums applied to order size or accounts receivable balances and represent the point at which the marginal present value of granting further credit becomes negative because of increases in risk or unit costs.

TEXT: Headnote: Trade credit limits trigger action in the management of accounts receivable. In practice, these limits are usually set by unaided managerial judgment. This paper develops two methodologies based on wealth maximization: information credit limits and risk credit limits. Information limits signal the need for additional credit investigation. Risk credit limits are maximums applied to order size or accounts receivable balances and represent the point at which the marginal present value of granting further credit becomes negative because of increases in risk or unit costs.

Trade credit is granted by one business to another in connection with the sale of goods or services. A trade credit limit is a policy instrument that applies either a maximum dollar receivables balance or a maximum order amount to a specific buyer. A seller can assign such a limit to any or all buyers. When the receivables or the order amount exceeds the credit limit, it signals the seller to take action. As a mechanism for policy implementation, one advantage of a credit limit is its simplicity. Once the credit limit is set, all that is required is a comparison of the limit with the current receivables balance or the amount of the order.

Trade credit limits are the most common tool in credit management. Over 85% of large firms use this tool, and they typically assign credit limits to more than 80% of their customers (Beranek and Scherr, 1991, and Besley and Osteryoung, 1985). While such a widely-used technique must have practical value, practitioners and researchers have little understanding of how it can enhance shareholder wealth.
By far the most popular method of setting credit limits is the analyst's judgment (Besley and Osteryoung, 1985). This may or may not lead to wealth maximization, depending on the analyst's skills and biases. Further, while practitioners almost always cite "risk control" as the primary motivation for using credit limits (Beranek and Scherr, 1991, and Besley and Osteryoung, 1985), there is little agreement among them as to what type of risk is controlled, although there appears to be a strong connection between credit limits policy and credit investigation expenses (Beranek and Scherr, 1991).

In this paper, I present a methodology for setting and using trade credit limits to enhance shareholder wealth. The following section uses a single-period framework to show how credit limits can be set when the seller is risk-neutral and the probability of the buyer's default does not increase with the amount of credit granted. Under these assumptions, credit

limits can act as triggers for expenditures on credit investigation. I call these "information credit limits." In Section II, I relax the assumptions of risk neutrality and invariant default probability and develop procedures for setting both information credit limits and "risk credit limits." Risk credit limits address changes in risk, default probability, and other factors that are affected by the amount of credit granted. (My discussions with trade credit practitioners indicate that they generally use the term "credit limit" to refer to any dollar value of a particular customer's orders or receivables that is used to trigger action, regardless of the type of action required. Consequently, though information and risk credit limits are quite different in purpose and application, I call them both "credit limits.") Section III explores the effects of administration costs, seasonality, future orders, and credit terms on information and risk credit limits and then examines the relationship between trade credit limits and the credit limits used in conjunction with consumer credit-card debt. Section IV summarizes and concludes the paper.

I. Credit Limits Under Risk Neutrality and Invariate Default Probability

Consider the trade credit-granting decision under the following assumptions:

1. The seller is risk-neutral.

2. The probability of the buyer's default or delinquency and the timing of the payment if the buyer does not default do not vary with the amount of credit granted.

3. The seller produces goods for sale at a constant cost per unit and sells these at a constant price regardless of order size. The seller faces no constraints on production capacity.

4. The seller can accept or reject orders without any effect on other cash flows (including those from future orders from the same buyer or orders from other buyers).

5. The seller can obtain information about the buyer by expending fixed costs associated with various levels of credit investigation. Information can come from any source, including the customer, credit-reporting agencies, financial databases, etc. This information is gathered in a sequential fashion, starting with the least expensive source of information and proceeding to more expensive sources. (This depiction of credit investigation as a sequential process follows Mehta, 1968, and Stowe, 1985.)

In this paper, I view credit decisions in the context of present value. This framework for evaluating those decisions was originally proposed by Hill and Riener (1979), Kim and Atkins (1978), Lieber and Orgler (1975), and Sartoris and Hill (1981 and 1983) and has since been used by many other authors. The applicability of these techniques and concepts to real-world sellers depends on whether the organizational structure of sellers' credit departments allows decisions to be made on a present-value basis. For various reasons, in some organizations the credit department's sole task (subject to certain organizational constraints) is minimizing credit-related costs. In such cases, a present-value approach that considers both costs and revenues is inappropriate.

With regard to risk-neutrality, I initially assume that the selling firm is indifferent to the variability of outcomes. If this is true, the expected net present value (NPV) of the cash flows from granting credit at the risk-free rate captures wealth effects. The risk-free rate is the appropriate discount rate since, when the seller is risk-neutral, the discount rate need only reflect the time value of money.

Note that this assumption ignores the effects of credit granting on the

seller's systematic risk. Ignoring systematic risk effects is justified if this type of risk is irrelevant to the credit-granting decision or if the correlation between default probability and the return on the market is sufficiently low that the effects on required return are unimportant. (For an exploration of the relationship between credit granting and systematic risk, see Copeland and Khoury, 1980.)

I also assume that the firm faces no production capacity constraints. Capacity constraints present the same problem as when the seller's total investment in accounts receivable is limited. When a seller faces capacity constraints, a portfolio approach to the credit decision is required. The seller chooses the best portfolio of credit risks among all potential buyers. (For discussion and development of a model for credit granting under capacity constraints, see Besley and Osteryoung,1984.)

Under the prior assumptions, because cash flows from future orders are not affected by the credit decision, the trade credit-granting decision has a one-period (one-order) horizon. This is consistent with much other research on credit-granting decisions; see, for example, Beranek and Taylor (1976), Scherr (1992), and Stowe (1985). Note also that for a given set of credit information, the size of the order is irrelevant to the credit-granting decision. To see this, assume that:

1. There are no taxes.

2. There are no recoveries in default.

3. There are no collection costs.

4. There are only two possible outcomes in credit granting: payment or default.

5. Productions costs are paid immediately.

6. No interest charges or penalties are imposed if the buyer pays beyond the due date.

Let X be the order size in dollars, V be the production cost per dollar sold, P be the probability of payment, t be the expected time to payment in days, and r be the yearly risk-free rate. Then, using a 360-day year:

$$E(NPV) = -XV + XP/(1 + r)^{t/360} \quad (1)$$

Applying the risk-neutral acceptance rule of E(NPV) > 0, then grant credit if:

$$0 < -XV + XP/(1 + r)^{t/360} \quad (2)$$

and dividing by X:

$$0 < -V + P/(1 + r)^{t/360}$$

Thus, the decision to grant credit is invariant to X as long as the remaining variables are not functions of X. For a given set of credit information about the buyer, order size is irrelevant if cost and price per unit do not vary in X. (Under these assumptions, credit information consists of estimates of P and t, which are the buyer-related parameters in Equation 3.)

This does not, however, mean that the credit-granting decision can be made regardless of order size because the effects of credit investigation expenses have not yet been addressed. A given set of information is assumed, but the seller's estimates of P and t will vary with the amount of credit investigation undertaken.

Mehta (1968) shows that in the presence of the fixed costs of different

types of credit information, decisions must be made simultaneously on the depth of credit investigation to be undertaken and to whom credit will be granted. Using a decision-tree approach to the problem, he develops rules for credit investigation that result in wealth-maximizing decisions based on the tradeoff between information costs and the other revenues and costs associated with credit granting. Stowe (1985) shows that Mehta's procedures can be formulated and solved as an integer program. This approach has an added advantage in that resource constraints can be incorporated in the algorithm.

These two approaches allow the analyst to formulate optimal credit investigation strategies for a given order size. But order sizes from a buyer can, and often do, grow over time. From a policy standpoint, credit managers are concerned not only with the optimal strategy for a particular order size but also with strategies for other order sizes. It is here that credit limits can be employed advantageously. If the credit investigation problem is formulated as a linear integer program, it can be solved to determine the particular order sizes for which additional credit investigation is optimal.1 I call these switch-points information credit limits.

Using information credit limits, credit investigation expenses are triggered by increases in order size. Prior credit investigation provides estimates of a customer's parameters, and the integer program's solutions reveal the next level at which further investigation should be performed. Though the mathematical programming processes are complex, the resulting policy is simple to understand and implement.

For example, retain all the prior assumptions, and also assume:

1. There are fixed costs associated with the various types of credit investigation.

2. There are only two stages of credit investigation: checking previous payment experience and ordering a credit report. The first costs $5 and the second, $50. Both costs are payable immediately.

3. There are three possible results of checking prior experience: good, poor, or none.

4. There are two possible credit reports on financial condition: strong and weak.

5. Costs of production are 80% of sales.

6. Order amounts are in increments of $100.

Given these assumptions, there are six types of customers (three types of past experience times two levels of financial strength for each experience type). There are therefore six sets of customer characteristics, each consisting of an estimated payment time and payment probability. Table 1 shows the assumed values of these characteristics and population probabilities of each buyer type. In this table, fiis the joint probability of a credit applicant with past payment experience i and rating j; t sub ij is the expected time to payment if payment is made; and P sub ij is the probability of payment. Let X be the order amount and r the risk-free rate. Applying Stowe's mathematics results in the integer programming formulation for this credit investigation and credit-granting problem illustrated in Table 2 for X = $500. (Notation in this table and throughout the paper follows Stowe, 1985.)

A brief review of Stowe's formulation may aid those who are not familiar with this methodology. The costs and revenues from credit granting, the probabilities of various outcomes, and the credit investigation costs are captured in the objective function.

The rules relating credit investigation and expected NPV are captured in the constraint equations. The objective function includes separate variables for the credit investigation costs and the probability-weighted expected NPVs of granting credit in various information situations. The coefficient of IMMGNT is the expected NPV of granting credit without any investigation. The coefficients of PEGGNT, PEPGNT, and PENGNT are the expected NPVs of granting credit to buyers with good, poor, and no prior experience, weighted by the probabilities of these payment experiences. Note that the sum of the coefficients of PEGGNT, PEPGNT, and PENGNT is the coefficient of IMMGNT. Similarly, the coefficients of the variables for the full-investigation conditions (GSGNT, GWGNT, NSGNT, NWGNT, PSGNT, and PWGNT) are the expected NPVs of granting credit for these values of P sub ij and t sub ij , weighted by the probability of the buyer type's occurrence. Note that the coefficient of GSGNT plus the coefficient of GWGNT equals the coefficient of PEGGNT (and similarly for PENGNT and PEPGNT).

The credit investigation expenses that are required to assess states of experience and rating are captured by the INVPE, PEGCR, PENCR, and PEPCR variables in the objective function. The coefficient of INVPE is the cost of checking credit experience. The coefficients of PEGCR, PEPCR, and PENCR are the costs of obtaining a credit report, weighted by the probability that past experience will be good, poor, or none. Note that in the objective function no variables represent the NPV of refusing credit. The credit investigation costs that are lost if credit is denied after investigation are captured by the INVPE, PEGCR, PENCR, and PEPCR variables.

Solving the integer program for various values of X gives the information credit limits. Solutions to the example problem appear in Table 3. For this example, an order should be approved without any credit investigation as long as the amount is less than or equal to $1,500 (since INVPE = 0 for these values of X). When an order for less than or equal to this amount is received, the information credit limit should be set at $1,500, and no credit investigation of the customer is required until order size exceeds this figure.2

An order above $1,500 requires further credit investigation. If the order is greater than $1,500 but less than or equal to $8,800, the optimal strategy (see Table 3) is to:

1. Check prior payment experience (since INVPE = 1 for these values of X).

2. If prior credit experience is poor, obtain a credit rating (since PEPCR = 1).

(Table Omitted)

3. If prior experience is poor and the credit rating is weak, reduce the amount of credit to be granted to zero (since PWGNT = 0). (This class of buyer always has a negative expected value of credit granting; the coefficient of PWGNT is negative for all values of X. For orders greater than $1,500, the revenues and costs of credit granting are large enough relative to the investigation cost to warrant a separate policy decision for these buyers.)

4. If past experience is poor but the credit rating is strong, grant unlimited credit. (This class of buyer has a positive expected NPV of credit granting; PSGNT is positive for all X. Under the assumptions of the problem, additional investigation is not possible, so the best decision is to grant unlimited credit to all buyers of this type.)

5. Grant unlimited credit to all applicants with good prior payment experience. (The net present value of granting credit to both strong and weak buyers with good payment experience is always positive; the coefficients of both GSGNT and GWGNT are positive for all values of X, so

it is never necessary to order a credit rating to distinguish between them.)

6. For buyers with no prior experience, grant credit without ordering a credit rating and set the information credit limit for these buyers to $8,800 (since PENCR is zero for volumes below this). Strong buyers with this payment record have positive expected NPVs (the coefficient of PSGNT is always positive) and weak buyers have negative NPVs (the coefficient of PWGNT is always negative). However, the proportions of these buyers and the revenues and costs from granting them credit make it unprofitable to distinguish between them until the amount owed is above $8,800.)

For amounts owed below $8,900, decisions resulting in either infinite (open) or zero credit are made for all buyers with good or poor payment records. Only buyers with no prior payment experience have finite, nonzero information credit limits. If the order volume reaches $8,900 for those buyers on whom the seller has no payment experience, the optimal strategy (see Table 3) is to:

1. Order a credit rating (since PENCR = 1).

2. Reduce the credit limit for weak buyers to zero (since the coefficient of NWGNT is negative for all values of X).

(Table Omitted) 3. Grant unlimited credit to strong buyers (since the coefficient of NSGNT is positive of all values of X).

II. Credit Limits with Risk Aversion or Changing Default Probability

Earlier, I assumed that the seller was risk-neutral with respect to credit granting, that goods were produced and sold at a constant dollar value per unit, and that the probability of the buyer's default did not increase with the amount of credit granted. Based on these assumptions, the amount of the order did not affect the decision to grant credit except as affected by the optimal amount of credit investigation. However, if these assumptions are relaxed, the credit-granting decision can depend on the amount of the order.

If Equation (1) is positive for small values of X but attains a unique optimum in X, additional order volume from the buyer beyond the optimum is not desirable. Several circumstances can result in such an optimum, including increasing costs per unit (V), decreasing price per unit (perhaps from demand curve effects), decreasing probability of payment (P), increasing time to pay (t), or increases in the seller's risk aversion with increases in receivable size.34 In this section, I discuss the effects of variations in V, P, t, and r on credit limits policy.5

One effect of increases in V, t, or r or of decreases in P with X is a reduction in those coefficients of the variables in the objective function that capture the probability-weighted net present value of credit granting. As V, t, or r increase or P decreases in X, the values of these coefficients are reduced relative to when V, P, t, or r are invariant in X. The reduction in these coefficients results in lower information credit limits. It produces different patterns of optimal credit investigation, particularly for values of X large enough that the coefficients of one or more variables change sign from positive to negative. This change indicates that the expected NPV of credit granting is negative for values of X greater than that resulting in the sign change.

(Table Omitted)

(Table Omitted)

In addition to triggering credit investigation, when V, t, or r increase with X or P decreases in X, rules based on order size can be used to limit

the size of the order to its optimal level. While information credit limits address credit investigation expenses, risk credit limits are used to optimize the expected NPV of the order, given the relationship between X and E(NPV).

Note that in this model, optimum order sizes caused by increases in r and decreases in P with X represent risk or the seller's response to it; optimums that occur because of increases in V or t are not really risk-based. I use the term "risk credit limits" to refer to all such optimums because I suspect that in practice most optimums in E(NPV) are caused by risk, and the term "Optimum E(NPV) Credit Limits" and other alternatives seem cumbersome.

Risk credit limits are obtained by finding the maximum E(NPV) in X (the maximum value of Equation 3), given the available information about the buyer. The risk credit limit can be greater or less than the information credit limit for the same buyer type. By enforcing risk credit limits (for example, by limiting order size), the seller can manage orders to maximize their net present values. Note that because setting risk credit limits requires estimates of the parameters of Equation (3), which in turn depend on the amount of credit investigation undertaken, risk credit limits and information credit limits are not independent.

As an example illustrating both types of limits, assume that for some classes of buyer, the probability of payment decreases with the amount of credit granted according to the logit function and that the probability of payment is described by:6

Probability of Payment = P sub ij - P sub ij /(+e sup a+bX) (4) where P sub ij is now interpreted as the probability of payment for an infinitesimally small amount of credit.7 The rate of decrease in payment probability with amount of credit granted depends on the parameters a and b, which can vary among the types of buyer. In addition to the prior assumptions of the numerical example, assume that the probability of payment declines for all buyers with weak financial positions and for buyers with poor prior payment experience but strong financial positions, according to the following conditions:

Figure 1 gives plots of probability of payment versus amount of credit granted for the first three conditions.

(Graph Omitted)

(Table Omitted) Given these data, calculating risk credit limits and information credit limits is straightforward. For information credit limits, the probability of payment for each type of buyer is calculated using Equation (4) for each level of X. These probabilities are then used in calculating the coefficients of the credit-granting variables in the objective function, and the integer program is iterated as before to obtain the switch-points. For risk credit limits, the order sizes resulting in the maximum NPVs are then calculated, given the investigation undertaken (and therefore the available estimates of payment probability and time to pay).8

A. Information Credit Limits
(Table Omitted)

The switch-points in the solutions to the integer program for the revised example problem appear in Table 4. There are several differences in these solutions relative to the prior results. Increases in the probability of default reduce the coefficients of all variables except GSGNT and NSGNT. (By assumption, the probabilities of default do not increase in X for buyers of these types.) This results in lower values for the first two switch-points. Specifically, the order value above which it is necessary to order credit reports on buyers with poor prior experience declines to $1,400 (from $1,500). The value above which it is necessary to order credit

reports on buyers with no prior payment experience declines to $5,000 (from $8,800).

In addition to lowering these two investigation strategy switch-points, two other information credit limits are introduced. The first of these occurs at $34,800. For orders of this size, the coefficient of PSGNT, which is positive for smaller values of X, becomes negative. The value of PWGNT is always negative, so the value of PEPGNT becomes negative. Granting credit of this amount to any buyer with poor prior experience has a negative expected value. Consequently, for orders of this size or larger, credit should be denied to all buyers with poor prior experience without ordering a credit report. Distinguishing between weak and strong buyers who have poor prior payment experience is not necessary.

The second new switch-point occurs at $35,400. For orders of this size, the coefficient of GWGNT, which is positive for smaller values of X, turns negative, and it becomes advantageous to order a credit report on buyers with good prior payment experience. Those with weak financials will be denied credit.

(Table Omitted)

A summary of the rules for information credit limits with changing default probabilities for the example problem is presented in Table 5. Perhaps of greatest interest in this table is the set of rules for order sizes greater than $1,400 but less than $5,100. For these order sizes, different information credit limits are set for buyers with different prior payment experiences.

B. Risk Credit Limits

If the order amount is less than $1,500, no investigation is optimal. The seller's estimate of the expected NPV for any level of credit granted is the sum of the expected NPVs for each type of buyer at that level of credit weighted by the probability of occurrence of that buyer type. When no credit investigation is undertaken, the maximum expected NPV occurs at an X of about $26,000 (see Figure 2). This is the risk credit limit for all buyers whose order size is less than $1,500.

(Graph Omitted)

Values for risk limits for other order sizes and investigation conditions are determined similarly and are shown in Table 6. Each is based on the expected present values of granting various levels of credit, given the remaining possible outcomes of the credit investigation process. For example, for order sizes between $1,500 and $5,000, if checking prior credit experience shows good prior payments, ordering a credit report is not necessary to distinguish between the two remaining outcomes: buyers who have good payment records and either strong or weak financials. The expected NPV of granting any level of credit is the probability-weighted average of the expected NPVs for these two buyer types. This average reaches a maximum at $38,000, which is the risk credit limit for these buyers.

In Table 6, as receivables size increases, if both limits are finite and nonzero, the lower of the two limits determines the action to be taken. If the information limit is lower than the risk limit, further investigation is triggered before the risk limit is reached, and the risk limit is not binding. If the risk limit is less than the information limit, the buyer's order size is restricted to the risk limit until order sizes are large enough to trigger additional credit investigation, in which case the risk and information credit limits are revised based on this investigation.

III. Extensions of the Model

The scope of the previously presented credit-limits model is limited by the assumptions under which the model is derived. This section discusses the effects of altering some of these assumptions.

A. Credit Limits and Administration Costs

The credit-granting model presented earlier was developed under the assumption that the only cash outflows associated with this decision were the production costs per unit sold (V) and the costs of credit investigation. However, the seller can also incur fixed costs in setting up and administering the relationship with the buyer (for example, mailing marketing materials, price changes notices, and other such expenses). It is partly as a reflection of these fixed administration costs that sellers offer quantity discounts and other volume-based incentives for larger purchases. Starting with the model in Equation (1), let A be the fixed costs of administering the account. Then:

(Formula Omitted) 2;2;0q Table 6. Risk and Information Credit Limits for Example Problem When Payment Probability Decreases with the Order Size

(Formula Omitted) and the credit-granting rule is:

Notice that in this situation, the decision to grant credit is no longer invariant in X. Dividing Equation (6) by X results in:

Since -AIX decreases in X (amortizing the costs of fixed administration costs over more units sold), higher sales volumes increase per-unit profitability. Selling to some buyers will be unprofitable for lower sales volumes but will be profitable for higher ones.

The effect on credit limits of incorporating administrative costs depends on the relationship between the administrative and production costs of the order (V). There are two possible
The first case requires no important modifications to the model. As long as the initial order is not past due, in which case payment for the initial order may be required before the additional order is approved, the additional order offers the same conditions to the seller as the initial one. This case does not differ from the one in which the initial order is for a larger amount. The combined amounts of the two orders determine credit investigation and credit granting.

(Table Omitted)

The second case is more complicated. Fewings (1992) shows that credit decisions can be reduced to the single current order even if additional orders are placed by the same buyer in any amount, as long as either 1) the estimates of default risk, time to pay, etc., are not expected to change over time or 2) these estimates are expected to deteriorate over time.

However, when estimates of default risk and payment time are expected to improve over time (creating a situation in which the current order has a negative expected NPV but future orders have positive expected NPVs), future orders are relevant to the initial credit decision. Unfortunately, attempts to model such credit decisions are mathematically cumbersome, limited by their assumptions about the evolution of default probabilities and payment times, and may not lead to a closed-form solution (see, for example, Bierman and Hausman, 1970, and Dirickx and Wakeman, 1976). This case is best regarded as a limitation to this and all other single-order credit-decision approaches.

D. Credit Limits and Credit Terms

A trade buyer's information and risk credit limits are not the only controls that sellers can impose. When the buyer's account is past due, the seller can require that the past-due items be paid for before additional

purchases are made, even if credit limits are not violated. (This is called "trading orders.") This process accelerates payments to the seller, but it requires that buyers be monitored not only on their credit limits but also on the due dates of prior purchases.

One way to enforce terms is to reduce the buyer's risk credit limit such that violation means that the buyer is past due. For example, suppose that terms are net 30 days, that the buyer is expected to purchase $10,000 per month, and that the buyer's risk credit limit is $15,000. If this limit is reduced to $10,000, its violation means that the customer is also past due, since more than one month's purchases are outstanding.
While this approach reduces the factors that have to be monitored, it has at least one disadvantage: Purchases beyond anticipated levels trigger action even if these purchases are caused by advantageous events, such as shifts in market share or the growth of the buyer's own sales volume. When risk credit limits monitor past-due status, the concept of the maximum amount of credit to be granted is masked. Action can be triggered when no action is required.

E. Credit Limits and Consumer Credit-Card Debt

While this article primarily concerns trade credit, it is useful to contrast this with consumer credit-card debt. Consumer credit-card debt and trade credit differ in a number of important ways. First, the dollar amounts of individual purchases and the total dollar amounts owing are typically much smaller for consumer debt. This means that much less credit investigation is advantageous. Also, in the U.S., the kinds of information that can be collected are limited by consumer protection laws, such as the Fair Credit Reporting Act and the Equal Credit Opportunity Act.

A second difference concerns the treatment of balances beyond the due date. For credit-card debt, these balances accrue interest at profitable rates. Consequently, granting credit to a consumer who pays after the due date is at least as profitable as granting credit to a customer who pays promptly. Therefore, unlike trade credit, analysis of credit granting is concerned almost entirely with a single aspect of the customer, the probability of default (rather than the probability of default and the time to pay).

These differences result in a considerably lower level of investigation for consumer credit than for trade credit. Typically, a consumer credit application is evaluated and an initial credit limit assigned using an inexpensive credit-scoring system.9 Updating the credit limit is based on payment experience, the cheapest source of credit information. This limit is a risk credit limit in that if the consumer violates it without contacting the credit-card firm first, credit may not be approved. However, the limit is also informational in that credit-card firms are generally willing to review it, based on payment experience, if the customer so requests.

IV. Summary

Credit managers must make decisions in the management of accounts receivable that maximize shareholder wealth. Practicing managers find that credit limits are useful tools in this process. Comparing the order amount or the receivables balance to a credit limit triggers wealth-enhancing action.

This normative paper provides methods for determining credit limits to manage credit investigation expenses and credit risk. It prescribes two sets of credit limits for these purposes, information credit limits and risk credit limits. While both sets of limits are expressed in terms of order size, they perform very different functions and are to be used by the seller in quite different ways. Information credit limits signal management of the order sizes at which additional credit investigation expenditures are most advantageous. Risk credit limits maximize the present values of

sales in the presence of risk or cost factors that increase with order size. Risk credit limits are imposed on buyers as maximum order sizes.

The procedure described here allows for revision of information about the buyer as payments are received (in the spirit of Bierman and Hausman, 1970). For example, suppose that a new buyer places an order and that this order is large enough to warrant a check of prior experience. This check will show "no experience" and the remainder of the credit investigation process is based on buyers of this experience type. Assume that credit is granted and that the receivable is paid or defaulted. If this buyer then places a second order and this second order is large enough to warrant a check of prior experience, the payment experience for the first order will be retrieved, and credit investigation will progress using rules for a different experience type. cases. One is that the administrative cost term captures an additional cost not included in the original model. The second is that the administrative cost represents a fixed component of V.

When the administrative cost represents an additional cost, the expected present value from granting credit for any level of sales is reduced by the amount of the administrative cost. Any buyer is less likely to represent an advantageous sale. Credit investigation at lower sales volumes is required to separate positive-NPV from negative-NPV buyers. Consequently, information credit limits are lower.

As an illustration, consider the original numerical example to which we add an administrative cost of $25. With this cost, the minimum order size necessary to check prior payment experience is reduced to $1,300 from $1,600, and the minimum order size necessary to require a credit report on buyers with no past experience is reduced to $7,600 from $8,900. (Calculations are available from the author.) However, risk credit limits are unaffected by such administrative costs because the deduction of a fixed amount from expected NPV does not change the point at which the expected NPV reaches its maximum.
When the administrative cost captures a fixed component of order cost, the addition of A to the model breaks the total cost of the order into fixed and variable components. When a portion of the total cost is fixed, lower sales volumes have higher total costs than when all costs are variable, while higher sales volumes have lower costs. For order sizes below breakeven, information credit limits are lower; for order sizes above breakeven, higher.

In the original information credit limits example, V = 0.80 and A = 0. Let A = $200 and V = 0.76. This structure produces the same total cost of $4,000 for an order size of $5,000; total costs are higher below this order size and lower above it. For these parameters, the minimum order size necessary to require a check of prior payment experience is reduced to $1,000 from $1,600, the result of this particular information credit limit being below the breakeven point. However, for V = 0.76 and A = $200, there is no order size large enough to warrant ordering a credit report on buyers with no past payment experience (as required at X = $8,900 for A = 0 and V = 0.80). This is so because for A = $200 and V = 0.76, buyers with no prior payment experience have positive expected NPVs at reasonably large order sizes whether their credit ratings are strong or weak. Consequently, it is not necessary to distinguish between them.
When the total cost of the order is decomposed into fixed and variable costs, all risk credit limits increase. These limits are not affected by the deduction of the fixed cost from expected NPV, but the reduction in variable cost causes the maximum in expected NPV to climb. B. Credit Limits and Seasonality

When there is seasonality in demand for the goods or services, there are times during the year when buyers come to the seller with larger order sizes. Using the model presented earlier, this means that on average more credit investigation is performed during these times, since the larger order sizes trigger additional levels of credit investigation. Credit

limits are set based on these higher levels of investigation. There are more buyers for whom credit ratings must be ordered, more buyers who have no information credit limits (a complete credit investigation having been performed), and more buyers who have either open or zero risk credit limits.

Seasonality also presents an interesting opportunity to consider the effects of inventory costs on credit policy. Emery (1987) applied peak-load pricing theory to this problem and found that there are some circumstances in which the seller should modify credit policy to address seasonality or uncertainty in demand. In slack periods, Emery argued, under some conditions, a firm should loosen credit policy. It should incur additional credit-related costs but reduce the inventory-carrying costs of producing goods during slack periods and storing them until peak periods.

In the model, all the costs of goods or services, including inventory carrying costs, are captured by V. When the firm sells from inventory and produces goods to replenish this inventory, it incurs inventory-carrying costs resulting from holding these goods until the next sale. During peak periods, the time between sales is less than during slack periods. Therefore, during slack periods there is a relatively greater opportunity to reduce inventory-carrying costs, resulting in a reduced V. Lower V leads to higher information and risk credit limits during these periods; optimal credit policy is looser. C. Credit Limits and Future Orders The model developed here is for a single order. An important extension concerns the effect of other orders on the strategies produced by the model. Consider two cases: 1. The buyer places an additional order before payment for the initial order has been made. The expected NPV of the initial order is negative (thus credit is not granted), but the buyer may place future orders, perhaps for larger dollar amounts.

Footnote: The contributions of the two reviewers in improving this paper are gratefully acknowledged.
1Stowe also shows how to express the linear program as a set of simultaneous equations that can be solved algebraically or graphically for the switch-points. However, in problems of practical size, this procedure may be cumbersome.

2Note that since order amounts are assumed to be in increments of $100, the next feasible order size above $1,500 is $1,600, and order sizes of $1,600 require a different pattern of credit investigation and credit decisions. The information credit limit is set at $1,500 because this is the maximum order size that does not trigger action; this is the way a credit limit is interpreted by practitioners. A violation of a credit limit (in this case, order sizes of $1,600 or greater) requires the credit manager to do something (in this case, perform additional credit investigation).

3For further discussion of these and other circumstances that can result in an optimum of E(NPV) in X, see Besley and Osteryoung (1984), Chua (1995), Copeland and Khoury (1980), and Scherr (1992). 4The prior discussion assumes that the seller is risk-neutral, thus cash flows are discounted at the risk-free rate. When the seller is not risk-neutral, the discount rate reflects the risk associated with the cash flows being discounted. One risk that can be priced this way is the effect on the seller's survival of a buyer's default. As the size of a particular receivable grows relative to other receivables, a larger portion of the seller's cash inflows come from that particular buyer, and default by the buyer increasingly affects the seller's ability to survive (see Scherr, 1992). To reflect this risk, the seller can increase the required retum as receivables size increases, which can produce an optimum in E(NPV).

5While I consider the effects of assumptions regarding these variables on the procedure for setting credit limits, other prior assumptions, when relaxed, can also affect this process. Discussion of the effects of taxes, collection costs, and similar other factors on the setting of information

credit limits is hla fr. th, -.th-.

6In the numerical example that follows, I allow P to vary rather than V, r, t, or some other parameter of the sale that may cause E(NPV) to take on an optimum in X. While the analysis is similar regardless of the parameter involved, survey evidence (Beranek and Scherr, 1991) indicates that about 30% of practitioners believe that the probability of payment decreases with

the amount of credit granted for some or all buyers. Therefore, I center on this parameter in my example.

7The logit function is employed in this illustration because of its simplicity and its mathematical properties: It makes the probability of payment a decreasing function in X and bounds this probability between Pj and zero. In practice, the function relating X and Pij is determined by the nature of the relationship that induces the payment probability to decrease with order size.

8 Unfortunately, while the logit function provides a simple relationship between payment probability and credit granted, substituting Equation (4) in Equation (3), differentiating with respect to X, and setting the result equal to zero does not lead the a function that is easily solved for X. (Contact the author for details.) The risk credit limits in the following example were obtained numerically.

9Use of credit-scoring systems is not limited to consumer credit. These systems are useful whenever the number of orders is large and the amount ordered by each customer is small, so that the costs of credit analysis itself are important. When applied to trade credit, these scoring systems are typically "expert systems," intended to replicate the judgment of a credit "expert," rather than systems based on present value concepts or on statistical analysis of defaults and nondefaults. See Srinivasan and Kim (1987 and 1988) for discussion of these systems.

Reference: References

Beranek, W. and F.C. Scherr, 1991, "On the Significance of Trade Credit Limits," Financial Practice and Education (Fall/Winter), 39-44. Beranek, W. and W. Taylor,1976, "Credit-Scoring Models and the Cut-Off Point-A Simplification," Decision Sciences (July), 394-404. Besley, S. and J.S. Osteryoung, 1984, "Accounts Receivable Management: The Development of a General Credit-Granting Algorithm for Determining Credit Limits under Funds Constraints," presented at the 1984 Financial Management Association Annual Meeting, held in Atlanta, Georgia.

Besley, S. and J.S. Osteryoung, 1985, "Survey of Current Practices in Establishing Trade-Credit Limits," Financial Review (February), 70-81.

Bierman, H., Jr. and W.H. Hausman,1970, "The Credit-Granting Decision," Management Science (April), B-591-B-632.

Chua, J.,1995, "A Trade Credit Decision Model with Order Size Dependent Credit Risks," University of Calgary Working Paper. Copeland, T.E. and N.T. Khoury, 1980, "A Theory of Credit Extensions with Default Risk and Systematic Risk," Engineering Economist (Fall), 35-52.
Dirickx, Y.M.I. and L. Wakeman, 1976, "An Extension of the Bierman-Hausman Model for Credit-Granting," Management Science (July), 1299-1237.

Emery, G.W.,1987, "An Optimal Financial Response to Variable Demand," Journal of Financial and Quantitative Analysis (June), 209-225. Fewings, D.R., 1992, "Trade Credit as a Markovian Decision Process with an Infinite Planning Horizon," Quarterly Journal of Business and Economics (Autumn), 51-79.

Hill, N.C. and K.D. Riener, 1979, "Determining the Cash Discount in the Firm's Credit Policy," Financial Management (Spring), 68-73. Kim, Y.H. and

J.C. Atkins, 1978, "Evaluating Investment in Accounts Receivable: A Wealth Maximizing Framework," Journal of Finance (May), 403-412.

Lieber, Z. and Y.E. Orgler, 1975, "An Integrated Model for Accounts Receivable Management," Management Science (October), 212-219. Mehta, D.,1 %8, "The Formulation of Credit Policy Models," Management Science (October), B-30-B-50.

Sartoris, W.L. and N.C. Hill, 1981, "Evaluating Credit Policy Alternatives: A Present Value Framework," Journal of Financial Research (Spring), 81-89. Sartoris, W.L. and N.C. Hill,1983, "A Generalized Cash Flow Approach to Short-Term Financial Decisions," Journal of Finance (May), 349-360.

Scherr, F.C., 1992, "Credit-Granting Decisions under Risk," Engineering Economist (Spring), 245-262.

Srinivasan, V. and Y.H. Kim, 1987, "Credit Granting: A Comparative Analysis of Classification Procedures," Journal of Finance (July), 665-681.

Srinivasan, V. and Y.H. Kim, 1988, "Designing Expert Financial Systems: A Case Study of Corporate Credit Management," Financial Management (Autumn), 33-43.

Stowe, J.D., 1985, "An Integer Programming Solution for the Optimal Investigation/Credit Granting Sequence," Financial Management (Summer), 66-76.

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